ASSESSMENT, DEVELOPMENT AND MANAGEMENT OF GROUNDWATER FROM CONFINED AQUIFERS OF A HILLY TERRAIN

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Civil Engineering

By

Santanu Kumar Sahoo

Roll No: 10301011

Department of Civil Engineering

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Under the Guidance of

Prof A.K. Pradhan

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Rourkela

CERTIFICATE

This is to certify that the project entitled, "ASSESSMENT, DEVELOPMENT AND MANAGEMENT OF GROUND WATER FROM CONFINED AQUIFERS OF A HILLY TERRAIN" submitted by Santanu Kumar Sahoo in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the project report has not been submitted to any other university / institute for the award of any Degree or Diploma.

Date:

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Date: May 03, 2007 Santanu Kumar Sahoo

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ABSTRACT

The object of the project is to study Characteristics of aquifer in the vicinity of National Institute of Technology, Rourkela Campus in assessing the ground water resources and the extent of utilization. The purpose of exploration was to establish aquifer constants such as transmissibility (T), storage coefficient(S), permeability (K) and yield through pumping tests. Several pumping tests, including those conducted this for project work, were carried out in non-equilibrium or unsteady state condition. The results were analyzed based on the following methods:

(a) Theis method of solution

(b) Jacob Method of solution

(c) Chow Method of solution

(d) Recovery Test

The results were interpreted and studied to get an idea of ground water potential and the yield. The results gave us an indication of satisfactory yield from the well (chosen for our project). The results of all the above tests are indicated in this project report.

The results obtained from the above tests confirmed that the confined aquifer existing in the said area can provide satisfactory amount of water for use at least for gardening purpose. For the use of this water for additional supply for the drinking purpose needs further tests for quality. This location being in the vicinity of an industrial area it is suspected that the ground water is likely to contain more iron contents than the prescribed limits. Therefore, it is suggested that the water from this well should be used for drinking purpose after confirming the quality through Physical Tests, Chemical Tests and Pathogenic tests etc.

SYMBOLS USED

a = Spacing of electrodes in WENNER Configuration

b = Spacing between potential electrodes in SCHLUMBERGER Configuration

V = Potential Difference between the two potential electrodes

I = Current flowing through current electrodes

R = Resistance of hemispherical soil mass enclosed between the potential electrodes

r = Distance between pumping well and observation well

Q = constant discharge from the pumping well

s = Draw down in the observation well

t = Time after pumping started

t' = Time after pumping was stopped

T = Transmissibility of the aquifer

W (u) = Well Function

t_0 = Time until drawdown was zero

s = Draw down difference per 100 cycles

s' = Residual draw down in the observation well during recovery.

List of Graphs

INTRODUCTION

At the minimum subsistence level most human beings, generally require about 2.5 litre of water per day. Normally the easier and convenient way to meet public demand of water is to utilize surface water resources. Unfortunately fresh water rivers and lakes are less plentiful than may at first be imagined and in fact account for less than 0.01 percent of world's total water and less than 2 per cent of world's fresh water. To complicate matters further this little fresh water tends to be distributed spatially and temporally in an irregular manner and while the sources that are available have often been overdeveloped or polluted. Groundwater on other hand accounts for about 98% of world's fresh water and is fairly well distributed throughout the world. It provides a reasonably constant supply which is not likely to dry up under natural conditions as surface sources may do and is often of quite a high quality.

Ground water schemes offer advantage of a different type in many overseas countries. In hot climates evaporation from surface of reservoir can be significant accounting for about 1/3 of total flow into reservoir. Also surface reservoirs are breeding ground for mosquitoes, increasing the incidence of malaria.

If ground water source is to be exploited, it is essential that entire project is conducted in most efficient and cost effective manner. This means that the wells must be designed so as to be efficient and pumps must operate at maximum efficiency for optimum benefits. This implies that every step of the operation must be planned and implemented in a predetermined logical order. Rushing into ground water development program may lead to incorrect location of wells and inadequate design leading to partial success of the project .

Thus realizing the importance of tapping the ground water sources and keeping in view water shortage in National Institute of Technology Campus during summer days, the then Water Resources Management Centre of this Institute established by the Ministry of Human Resources and Development, Government of India, started investigation of under ground strata in the valley since 1984-85 to locate ground water. Rourkela is a big industrial complex surrounded by Durgapur Hill range. The Rourkela valley surrounded by hill range is made up of permeable gravelly subsoil formations. A perennial river, Koel, flows in the middle of this valley from which campus meets its demand of water for various purposes through a suitable water supply system.

The Rourkela valley receives an annual average rainfall of about 150 cms. The National Institute of Technology campus with a population of about 6000 and situated at the foot of the hill ranges about 3 KM. from the river Koel. **Hilly terrains are generally considered to be good groundwater sources as underground formations get recharged through cleavages, fissures, faults etc**. Moreover, Confined aquifers remain almost free from pollution and fluctuation of yield with season.

An area of about 8 hectares in the campus was chosen for exploration tests and it was found out that a shallow aquifer of about 30 to 60 meters floats over an impervious strata. Further studies were undertaken to determine aquifer constants and to know ground water potential.

A number of deep tube wells penetrating confined aquifers have been proposed to meet adequately the demand of water for various uses. 20 points, distributed all over the area had been located for detailed studies for assessment of water resources to make optimal uses of ground water.

This particular project is a part of the research work to study the yield and other behaviors of the confined aquifer of a particular point near open air theatre. This project includes location of potential ground water point for installation of tube well through surface and subsurface investigations, drilling of well, installation of casing, development of deep well, installation of pump and conducting pumping test etc. The aim was to analyze the test results and determine aquifer constants and suggest effective utilization of ground water obtained from this tube well.

OBJECTIVE OF THE PROJECT

The original project is a basic research regarding characteristics and behaviors of confined aquifer in Durgapur hilly terrain which is adequately recharged with rain water in monsoon period. This project aims at determining behavior of the aquifer with respect to quantity. Yield and movement from the formation constantssuch as Storage co-efficient(S),Transmissibility(T) and permeability(K). This has been achieved by studying pumping and recovery test data over a wide range of time. This particular report contains analysis of test data for summer period only.

Chapter 1

SURFACE INVESTIGATION

1. SURFACE INVESTIGATION

Although groundwater cannot be seen on the earth's surface, a variety of techniques can provide information concerning its occurrence and under certain conditions even its quality. Surface investigation helps us in finding the information about the type, porosity, water content and compactness of subsurface formation. It is generally done with the aid of electrical and seismic properties of earth and without any drilling on the surface. The information supplied by these techniques are partially reliable and involve less expenditure. It provided only indirect indications of groundwater so that underground hydrologic data must be inferred from surface investigations. Correct interpretations require supplementary data from subsurface investigations to substantiate surface findings. It is mainly achieved by the Geophysical method viz, Electrical resistivity & Seismic refraction method.

1.1Electrical Resistivity Method

The electrical resistivity of a rock formation limits the amount of current passing through the formation when an electric potential is applied. It may be defined as the resistance in ohms between opposite faces of a unit cube of the material. If a material of resistance R, Cross sectional area A and a length L then its Resistivity

Can be expressed as

$$\rho = R.A/L$$

Units of Resistivity are ohm -m^2/m or simply ohm-m. Actual resistivities are determined from apparent resistivities which are defined as the proportionality factor in the equation relating the measured electrical resistance R of the electrical field to the mean path length L of the current and the mean Cross Sectional Area A_c of the electrical field or

$$R = R_a .L_c/A_c$$

In the electric resistivity method the electric resistance determined by applying an electric current (I) to metal stacks (outer electrodes) driven into the ground and measuring the apparent potential difference (V) between two inner electrodes (non-polarizing D.C. type i.e. porous pots filled with $CuSO_4$ solution and metal stakes in a.c. type) buried or driven into the ground. Fig. gives us an indication of the type and depth of subsurface material. Changing the spacing of electrodes changes the depth of penetration of the current and the apparent resistivity obtained at different depths by measuring the resistance R=V/I is plotted on a semi-log or log-log paper against the depth. The depth at which the current enters a formation of higher or lower resistivity is signaled by a change in the resistivity recorded at the ground surface. By proper interpretation of the resistivity data from the field curves so obtained and matching them with the standard curves available it is possible to identify water bearing formations and accordingly limit the depth of well drilling. Different geological strata have different electrical resistivity. They are classified and identified in terms of their characteristic resistivity. Experience and research have enabled difference in electrical resistivity to be interpreted in terms of geologic strata, porosity, water content and composition.

Electrical current can pass through the rocks only because of conducting minerals present in them and the water content of the rocks. So rocks are good insulators when they are free from conducting minerals and water is present in them. The electrical resistivity of a stratum depends on the materials of formation, density, porosity, pore size and shape, water content, quality and temperature of water.

The ground water resistivity also depends on temperature of dissolved minerals. With increase of temperature and dissolved minerals water shows greater ionic mobility and lesser resistivity. As the depth of water increases its temperature and hence resistivity also varies. The following are approximate values of resistivity for different type of water.

Type of water	***Resistivity in ohm-m***
1. Meteoric water (derived from precipitation)	30 - 1000
2. Surface water (in districts of igneous rocks)	30 - 500
3. Surface water (in districts of sedimentary rocks)	10-100
4. Ground water (in areas of igneous rocks)	30 - 150
5. Ground water (in areas of sedimentary rocks)	more than 1
6. Sea water	0.20

Both porous and non porous rocks behave as insulators until they are in dry condition. Resistance decreases with increase in pore water. Unconsolidated material has more resistance than compacted materials of same composition. Sedimentary rock has better conductance i.e. lesser resistance than the igneous rocks. Clay has higher conductivity than sand because of presence of iron cluster on surface of clay. Based on these know ledges from resistivity survey it is possible to distinguish between major rock groups and the water bearing zones.

The following are electrical resistivities of some common materials.

Composition	***Resistivity in ohm-m***
Top Soil	5-50
Silt and clay	8-50
Clay sand and gravel mixture	90-250
Saturated sand & Gravel	40-100
Moist to dry sand and Gravel	100-3000
Mud stone & shale	8-100
Sand stone 8 lime stone	100-1000
Crystalline rocks	100-10,000
Quartz	100
Calcite	500
Dense granite	10,00,000
Metamorphic rocks	100-100,000,000
Unconsolidated sedimentary rock	10-10,000
Gravel and sand with water	100
Fresh water	100
Shale and clay	10
Brine	0.05

There are mainly two common types of electrode arrangement. In the Wenner configuration the electrodes are spaced at equal distances a, which is shown in fig.
The apparent resistivity ρ_a of a measured resistance R(V/I) is given by

$$\rho_a = 2\pi aR$$

and the field curves are plotted on a semi-log paper ρ_a versus a.ρ_a being in ohm — meter in logarithmic scale and a in meter in arithmetic scale.
In Schlumberger configuration fig (b) the distance between two inner Potential electrodes (b) is kept constant for some time and the distance between the current electrodes (L) is varied.
The apparent Resistivity for a measured resistance

R = V/I is given.

$$\rho = \pi R\{[(L/2)^2 - (b/2)^2]/b\} \quad ,L>>b$$

$$\rho = \pi L^2R/4b \qquad \text{if } L>>5b$$

and the field curve is plotted on a log- log paper ρ verses L/2 ρ being in ohm-meter and L/2 in meters.

1.2ASRM Two Pin Method:

As the name suggests the method involves use of two pin (electrodes or probes). In this method a reference probe is to be hammered into the ground at the central point in the locality. The other probe is to be shifted from place to place along the periphery, keeping the distance from the reference probe almost equal. The reference probe is termed
P-3 and the searching probe is termed P—2. The connecting wires are connected to the respective terminals on the main meter. A.D.C. supply from a charged battery (at least showing 30—40 volts) is to be maintained. The meter uses D.C source to produce required 50v A.C., 100 V A.C., 200V A.C., and 400 V A.C source internally connected to P2 and through the meter itself. The meter functions as standard resistance measuring meter and gives the resistance between the two probes. There is a provision for different range selection i.e. x 1, x 10, x 10^2, x 10^3, x 10^4

These selectors thus make the capability of the meter to measure from 0.001 ohms to 9999 ohms. The following are different Steps used in using the meter for the above purpose:

1. The battery is connected to the meter and selecting the output voltage (usually 50 V ac) the input voltage is checked.
2. Then a particular range is chosen and the meter adjusted and calibrated.
3. Connecting the probes it is checked for Continuity.

If there is poor continuity the point can be watered and probe can be hammered deep.

4. The resistance is measured by use of sensitivity knob and ten—turn potentiometer knob. The resistance is given by the product of potentiometer reading and the range selector. The reading is accurate when the meters read the minimum value at maximum sensitivity.
5. Thus the resistance between P and P is measured and then the distance between electrodes is changed for next reading.

In the two point system after completing the horizon the point for lowest resistance is selected and P probe placed there. Then the P probe is once again moved about P and the resistance between P and P is measured. Finally the location of P for which the resistance between P and P is minimum is found. That point is the most suitable point for location of well in the locality. The next higher point is usually selected for point for observation well (But here that point being much nearer to main well Point was rejected and the next higher point was suggested for observation well)

1.3 ASRM FOUR PIN METHOD

In this four pin method ‘WENNER’ configuration is used in measuring resistivity. Four electrodes are hammered equal distance apart (between each successive probes) about the particular point along a straight line. The two extreme electrodes end are connected to the battery through the meter. The range selector switch is passed for required range. All band switches are kept in off positions after adjusting the meter accurately. The connecting lines from the probes are connected to the respective terminals on the meter. Now using the TEN TURN POTENTIO METER knob and sensitivity knob the sensitivity of the hemisphere mass between P2 and P 3 is measured. Apparent resistivity readings are taken at increasing spacing ‘a’ (a = 1, 2, 3,.,. .meters) and plotted against electrode spacing ‘a’. Remarkable change in resistivity occur in the water bearing zone, resistivity logs are to be correctly interpreted bearing the following points in mind.
The depth of the strata is equal to electrode spacing. The water bearing zone is Indicated by sharp dip of the curve. Then reading drops to less than 50% of preceding reading, then only it gives a sure indication of change of strata. It has been found that hard rock sensitivity is three times or more than that of top soil.

Soft rock sensitivity is twice higher than the top soil resistivity. The results of resistivity survey should be preferably studied with the sub surface investigation data.

1.3.1 DESCRIPTION OF THE INSTRUMENT:

1.3.1.1. Current Indicator: —

At the left hand top Corner the RED push button mark CURRENT is situated. During the operation when this push button is pressed the current penetrating into the ground (between P1 and P4 circuits) is measured on the meter. If the Current button is pressed and the pointer of the meter stands at say 20; it means that the Current flow is 50 milli amps (2.5 times the reading on the meter).

1.3.1.2. Voltage Selector: —

Below the Current push button the voltage selector knob
is located. With this the output A.C. voltage is to be selected at different stages, viz., 50 VAC, 100 VAC., 200 VAC and 400 VAC.

1.3.1.3. Range Selector: —

Below the voltage switch there are five different ranges viz x 1, xlO, x 100 , x 1000 , X 10000

In the first range, ie., x 1 Is the resistance up to 1 ohm can be measured. In the second range that is x 10 resistance up to 10 ohms can be measured and so on.

1.3.1.4. Terminals: —

At the lower end there are 4 terminals marked P1, P2,P3,P4. P1 and P4 are of RED color whereas P2 and P3 are BLACK color. P1 and P4 are connected to current which current is penetrated into the ground as P2 and P3 are connected to potential created by current probes.

1.3.1.5. On/Off switch: —

With this toggle switch the instrument can be switched ON AND OFF. This is in D.C. battery circuits.

1.3.1.6. CAL KNOB: —

With this knob, the instrument is to be calibrated. Once the instrument is calibrated for a particular range then this knob is not to be disturbed till the required set of readings is obtained.

1.3.1.7. Meter: —

The meter is used for 3 different functions:

(1) Current indication:

When the probes are connected with the instrument and the instrument is switched ON and in this condition of the current button is pressed, the meter indicates current flow into the ground in Milli Amps. Here the full-scale deflection (i.e., 100) indicates 250 Milli Amps).

II) Battery indication:

When the press button marked Battery is pressed the meter shows battery voltage(Input). The green region indicates the required battery voltage. The instrument works properly of the input battery voltage is between 4.5 V D.C. The battery to be charged when it shows 4 volts. When the main switch is OFF, the battery voltage can be rested and it also shows the proper connection (polarity) from the battery to the instrument

III) Null balancing:

This is for taking the actual readings of the ground. Null balancing technique is adopted that is the minimum deflection of the pointer is towards left side i.e., “0”side of the meter.

1.3.1.8. Neon Indicator:--

When the instrument is switched ON the neon RED lamp on the top of the meter glows indicating the developing A.C voltage.

1.3.1.9. Battery Indicator: —

At the right hand corner there is a press button marked Battery. When this button is pressed the meter pointer shows the condition of battery i.e., input voltage. It should be always in the green region marked on the meter. When the main switch is OFF the battery may show more voltage because of unload condition and when the main switch is ‘ON’ the voltage may go down. But in either case the pointer must show (minimum voltage required) 4.5 V.D.C. or more.

1.3.1.10. Sensitivity:

This BLACK knob situated at the right hand side below the battery press button. When this knob is rotated clockwise (right hand side) the sensitivity increases i.e., deflection is more and the null balancing can be done more precisely and sharp.

1.3.1.11. Ten turn Potentiometer knob — ‘R’ knob:

The knob is situated right below the Sensitivity knob. It measures the resistance accurately. The least count of this knob is 0.001 ohms and when the full ten turns are completed it measures 1 ohm. This will measure resistance between 0 and 1.0000 ohm of the range Selected is xl. will measure ten ohms when the range selected is x 10. It will measure 100 ohms if the range selected is x 10

It will measure 1000 ohms of the range selected is x 10 It will measure 10,000 ohms if the range is x 10 In other words the reading is to be multiplied by the range selected.

Various Resistivity Survey were conducted at the open air theater and the observations were analyzed with help of computer.

The results are given in tabular form in the print attached herewith. A graph between apparent resistivity versus Depth was drawn and various inferences drawn from it are shown in the graph.

Chapter 2

SUB-SURFACE INVESTIGATION

2. SUBSURFACE INVESTIGATION

Sub surface investigations have paramount importance to ascertain accuracy of results obtained from Surface investigation techniques. Undoubtedly methods of sub—surface investigations are much costlier than available surface investigation techniques. However, for a large project it is wiser to go for the former methods as accurate results are very important for success of the project. At National Institute of Technology, Rourkela, the water resources Management Centre and Rourkela Steel Plant jointly carried out subsurface investigation, for effective planning of Groundwater Project. This was necessitated due to the yield of black silty water in a few tube wells in the campus. Other tube wells yielded fairly good water. It was inferred that the result of the surface investigation cannot be fully relied upon.

Two diamond drills(Jey 22 HD, M/s Voltas Ltd.,and Leng— year 34, L&T,) of core size 2.16" and 1.66" respectively were employed from mid January 1987 to end of March 1987 to drill five bore holes located at different locations in the campus. Because of soft nature of the formation dry drilling method was used for maximum core recovery. Presence of water table located at 5.0 meters below the ground level posed operational troubles owing to constant caving in. Hence, NX and BX casings were lowered to avoid collapse of side walls.

The core drilling established the existence of two successive horizons of Quartz, Mica, Schist and Carbonaceous Phylites below a top mantle of lateritic soil. The schist and phylites showed evidence of intense weathering and decomposition up to considerable depth, thereby developing permeability and forming aquifers. The carbon phylites in weathered and decomposed conditions crumble to very fine sooty material and come along with water and black color.

The hand and fresh mica, schist and carbon phylites below the weathered portion were impervious and limits the flow of ground water. Thus the sub—surface investigations strengthened the interpretation of surface investigation and helped in proposing remedial measures to be taken for obtaining water of suitable quality.

The various well logs as prepared by the Water Resources Management Centre are given in the subsequent pages.

2.1 BORE HOLE LOG

2.1.1 Location: Pooja Mandap (Figure 1)

MEGASCOPIC DESCRIPTION OF CORE

DARK BROWN LATERITE SOIL HIGHLY DECOMPOSED POWDERY MICA SCHIST AND SOIL HIGHLY DECOMPOSED DARK YELLOW TO I1ROWN IN COLOUR POWDERY MICA SCHIST WITH PREDOMINANT MUSCOVITE AND OCCASIONAL PIECES OF VEIN QUARTZ. WATER TABLE TOUCHED AT 4.57 m. HARD PIECES OF PARTLY DECOMPOSED MICA, SCHIST QUARTZ WITH MUSCOVITE & BIOTITE PIECES OF VEIN QUARTZ& DECOMPOSED POWDERY SCHIST.BROKEN PIECES OF HARD AND PARTLY DECOMPOSED CORE OF QUARTZ MICA SCHIST WITH WELL DEVELOPED FOLIATION PLANES ALONGWI TH CORE BREAKS DECOMPOSED QUARTZ MICA SCHIST IN POWDERY FORM HARD & FRESH CORE OF QUARTZ MICA SCHIST, IMPERVIOUS IN NATURE, SHOWING VERY LITTLE DECOMPOSITION: HARDNESS 1NCREASES WITH DEPTH CORE SHOWS A DIP OF 50 BORE HOLES CLOSED.

2.1.2 Location: Hall 4 (Figure 2)

MEGASCOPIC DESCRIPTION OF THE CORE

DARK BROWN LATERITE SOIL, HIGHLY DECOMPOSE MICA SCHIST WITH TOP SOIL AND OCHREOUS MATERIAL. HIGHLY DECOMPOSED POWDERY MICA SCHIST, VARYING IN COLOUR FROM LIGHT GREY, YELLOW, LIGHT PINK TO LIGHT ASH. WATER TABLE WAS TOUCHED AT A DEPTH 4.88 M. HARD BUT WEATHERED PIECES (10 cm) OF QUARTZ SCHIST AT TOP, FOLLOWED BY POWDERY DECOMPOSED QUARTZ SCHIST & QUARTZ MICA SCHIST ARENACEOUS MATERIALS PREDOMINANT OVER MICACEOUS MATERIALS WITH DEPTH COLOUR MOSTLY GREY. MIXTURE OF HIGHLY DECOMPOSED QUARTZ MICA SCHIST AND CARBONACIOUS PHYLLITES IN POWDERY FORM WITH VARIEATED COLOURS APPEARS TO BE THE TRANSITION ZONE BETWEEN MICA SCHIST AND CARBON PHYLLITES.

HIGHLY DECOMPOSED SOFT AND POWDERY SOOTY CARBON PHYLLITES VARYING IN COLOUR FROM DEEP ASH TO BLACK AT SPACES. THE ROCK IS MOSTLY SILICEOUS. BORE HOLE CLOSED.

2.1.3 Location: Open Air Theatre (Figure 3)

MEGASCOPIC DESCRIPTION OF THE CORE

DARK BROWN LATERITE SOIL LIGHT YELLOW POWDERED AND FRIABLE PIECES OF HIGHLY DECOMPOSED QUARTZ MICA SCHIST WITH TOP SOIL AND OCHRECEOUS MATERIALS. WATER TABLE TOUCHED AT 4.86 m DEPTH. HIGHLY DECOMPOSED QUARTZ MICA SCHIST IN POWDERY FORM, COLOUR VARYING FROM LIGHT BROWN AND GREY TO LIGHT PINK AT PLACES. HIGHLY DECOMPOSED QUARTZ MICA SCHIST IN POWDERY FORM ALONGWITH OCCASIONAL LHARD BUT WEATHERED PIECES OF QUARTZ SCHIST AND VEIN QUARTZ WITH LIMONITIC STAIN AT PLACES • LITTLE CARBONACEOUS MATERIAL ALSO ADMIXED AS OBSERVED FROM THE INTERMITTENT AND COLOUR BORE HOLE CLOSED.

2.1.4 Location: G-Block (Figure 4)

MEGASCOPIC DESCRIPTION OF THE CORE

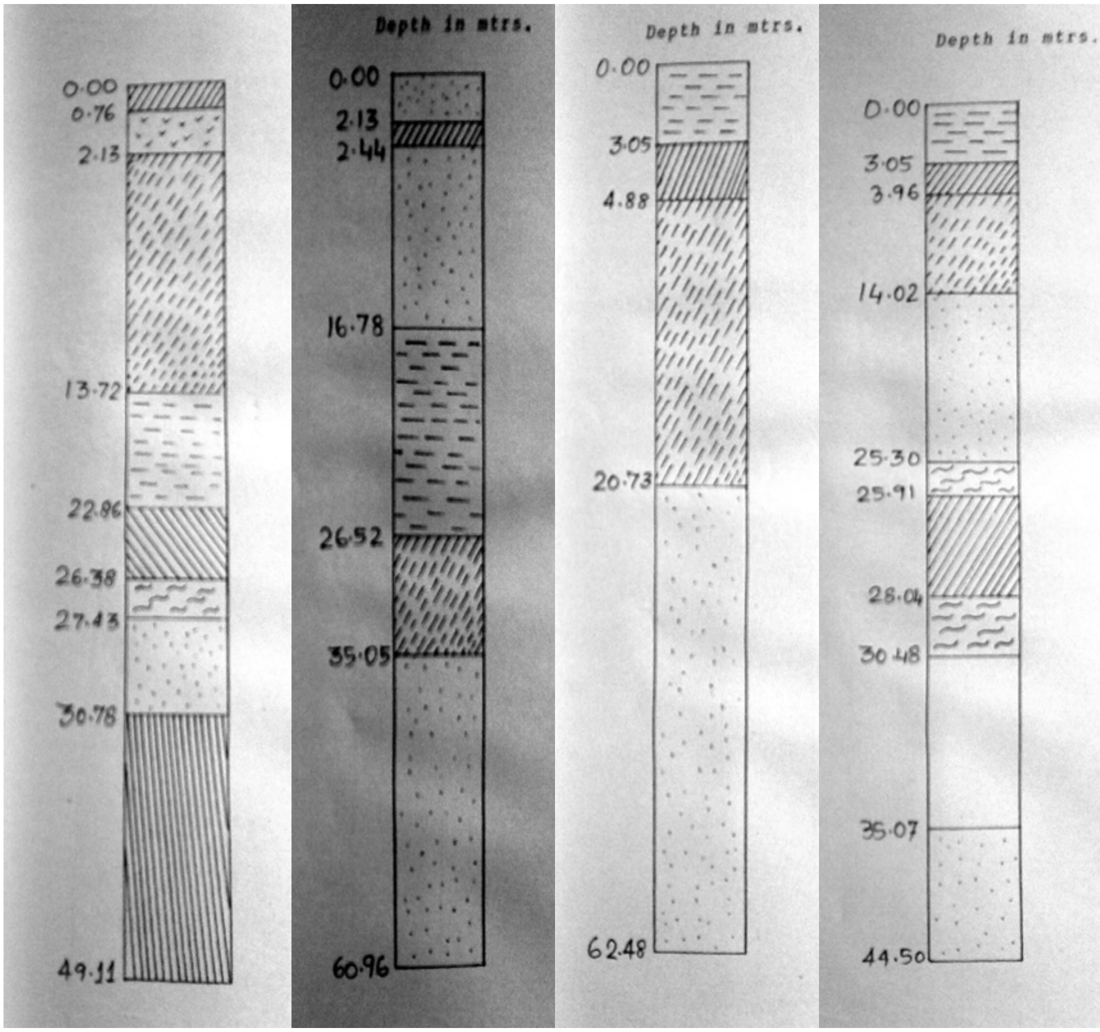
DARK BROWN LATERITE SOIL LATERITIC SOIL. MIXED WITH HIGHLY DECOMPOSED MICA SCHIST & PEBBLES OF VEIN QUARTZ LIGHT YELLOW PINK TO LIGHT BROWN COLOURED HIGHLY DECOMPOSED MICA SCHIST, SOFT.CRUMBLES TABLE TOUCHED AT 8.53 m. HIGHLY DECOMPOSED MICA SCHIST RECONVERED IN POWDERY FORM WITH A FEW PIECES OF PHYLLITE & QUARTZITE. THE MATERIAL WAS SANDY AT PLACES, COLOUR WAS SIDEL VARYING. COURSE TO MEDIUM GRAINED SANDY POWDER OF DECOL MPOSED QUARTZ MICA SCHIST/QUARTZ SCHIST PARTLY DECOMPOSED OF QUARTZ MICA SCHIST WITH SLEEDE OF THE SAME ROCK TOP O.6lm COARSE TO FINE GRAII'JED SANDY POWDER. POSSIBLY OF QUARTZ MICA SCHIST, REST, WERE FRAGMENTED CORE OF DECOMPOSED QUARTZ MICA SCHIST. LIGHT YELLOW AND GREY COLOURED SANDY POWDER OF DECOMPOSED QUARTZ MICA SCHIST/QUARTZ SCIJIST

HARD 8 COMPATED CORE OFIMPERVIOUS QUARTZ MICA SCHIST. BORE HOLE CLOSED.

2.1.5 Location: N.I.T (Figure 5)

MEGASCOPIC DESCRIPTION OF THE CORE

BROWN LATERITE SOIL LIGHT BROWN LATERITE SOIL WITH HIGHLY DECOMPOSED MICA SCHIST. LIGHT YELLOW AND GREY TO LIGHT BROWN COLOURED DECOMPOSED MICA SCHIST. WATER TABLE ENCOUNTERED AT 6.70 H DEPTHS. POWDERED AND FRAGMENTED PIECES OF MICA SCHIST BROKEN PIECES INDICATING PARTIAL WEATHERING. FIRST 0.61 H SANDY POWDERS POSSIBLE OF QUARTER MICA SCHIST, THE REST BEING HARD CORE 8 PIECES OF QUARTER MICA SCHIST. BOTTOM HARD CORE OF QUARTER MICA SCHIST REST WERE DECOMPOSED MATERIAL OF THE SAME ROCK. HARD CORE & SLUDGE OF QUARTER MICA SCHIST. HARD&COMPACTED. FOLIATED QUARTZ MICA SCHIST.BORE HOLE CLOSED.



0.00
0.76
2.13
13.72
22.86
26.38
27.43
30.78
49.11
Depth in mtrs.
0.00
2.13
2.44
16.78
26.52
35.05
60.96
Depth in mtrs.
0.00
3.05
4.88
20.73
62.48
Depth in mtrs.
0.00
3.05
3.96
14.02
25.30
25.91
28.04
30.48
35.07
44.50

Figure

1 2 3 4

Chapter 3

DRILLING OF HOLES

3. DRILLING OF HOLES

As reported by the then Water Resources Management Centre after points for location of main well and observation well were established from the surface and sub-surface investigations the next operation of the project was to drill tube wells in different phases. The diameter of main well is 150mm and that of observation well is 125mm. Increase in well diameters does not affect much on discharge. The size of 150mm main tube well suited well to the outer diameter of submersible pump, installed to pump out water.

At the points near open Air theatre, the drilling contracts were given to P.H.Division, Rourkela for the main well and the observation well. They used the DTH method of drilling, The drilling of observation well started first. They were having drill bits of 8”, 6” size. The length of drilling rod used was 5 meters long. During drilling the cutting samples were collected at every 10.00 feet intetva1s the time taken for drilling every 10 feet was recorded and the sample collected were observed at the site and also dept for future references.

In the main tube well hard rock layer was encountered at a depth of 173’lO” and hence the drilling was stopped. Then casing was put up to the hard rock and drilling was continued up to 220’. The bit size used beyond 173’10” was 4.25” diameter. The water level was at 5’ below the G.L in the observation well.

3.1 INSTALLATION OF CASING

The casings in deep tube wells serve as lining, maintain an open hole from ground surface to the aquifer. It provides structural support against caving and also scals out surface water and water bearing layers. In the main well point yield steel and galvanised iron pipes are used for casing. But, now—a days the synthetic (HDPE) pipes have started replacing conventional G.I. pipes for obvious means. The synthetic pipes have the advantages of being corrosion resistive over the mild steel better known as stainless steel pipes. The synthetic (HDPE) pipe have a reasonably long life span. These are also light and easy to handle.

However, for this particular case G.I. casing pipes were preferred because the soil strata were very hard and the G.I Pipes were easily available. Pipes of required diameter were available in a standard length of 5 meter and were used for casing. The buoyancy plug and strainer pipes were also available. The pipes of 5m length were joined together permanently as per the requirement at the site itself.

The inner diameter of the G.I casing pipe used was 150 mm. For the main well 53.59 meter of 6” G.I pipes and 9 nos of G.I sockets of 6” were used.

The casing was lowered for almost the entire depth with gap left at the bottom to allow flow of from the underlying formation. The casing was

lowered up to 54 meters depth. Beyond this no casing was required due to presence of hard strata. The casing was installed by the drilling agency, Under the supervision of technical personnel of the Water Resources Management Centre, National Institute of Technology, Rourkela.There was hardly any need for packing of sides. The casing was fitted tightly in the drilled well. Even it was to be hammered at times. The side gaps extending up to few meters from ground level were filled with earth and were compacted manually.

3.2 DEVELOPMENT OF WELLS

Well development or simulation has been defined as treatment of a well by mechanical chemical or other means for the purpose of removing an underground resistance to flow. Development of well includes the steps to increase the specific capacity of the well, to prevent sand intrusion, to obtain maximum economic life and to improve the quality of Water. There are a number of procedures available for well development, with different purposes. Some of them are pump in surging, surging with air, back washing with air, back washing with air, hydraulic jetting, use of chemicals, hydraulic fracturing etc. In this particular case surging with air method was adopted.

The details of work that was carried out are explained here.After the completion of drilling of main tube well, the well was flushed. The water was found carrying loose black cotton particles. It was suspected that the particles were coming from the underground strata because of excess drilling up to 220’. In the first operation of well Development the bottom was plugged to arrest the Upward flow of the unwanted materials. The plug was a 4” diameter and 10’ long G.I. pipe filled with coarse aggregate and closed at both ends by solid mild steel plate and hook at the top. It was inserted through the casing and settled at the bottom due to its heavy weight. Drill rods were inserted to check up the plug was at right place. Rounded pebbles were also inserted into the well. The sizes of the pebbles were 1“to 1”. After this composed air were released reasonable depths of the well. Flushing by this method was carried out for 3.5 hrs. Samples of water were collected after two hours of flushing and again at the end. The sale collected at the end was found to be completely clear. The discharge from the well was measured by time—rise method and also by a v— notch. The discharge was found to be 5100 cum per hour. The V—notch was 2.5” size with 90° angle between the faces. The water level in the main well was 5’ below ground level.

3.3 WELL STERILISATION

It is a good practice to periodically disinfect a well during the drilling operations while any water that is intruded into the well during drilling or well development should be of drinking water quality. Similarly, gravel pack material should be disinfected before being placed in a well. Well provides a direct connection between the ground surface and the ground water resources, and care be taken so that pathogenic bacteria are not allowed to enter the aquifer during the construction process.

Disinfection or sterilization is usually accomplished by introducing chlorine into the water in the well and the adjoining aquifer.

3.4 INSTALLATION OF SUBMERSIBLE PUMP

After the completion of drilling, installment of casing, well development and sterilization pump of suitable size and capacity was installed. As the suction head of pumps are usually very low, it was decided to install a submersible pump. The water from this tube well is planned to be directly pumped to the pump situated near the foot hill carried through the existing mainline of the surface water supply system for campus use and also to the college through a branch line.

The WASP submersible pump of water supply specialties Pvt. Ltd,Bombay is used for this particular project. The submersible pump requires less space, eliminate expensive foundation and pump house arrangements. It has noise—less operation and uses water as lubricating material.

The pump was found suitable as per the requirements and was installed; the supply agency had come to the site fro the installation. The pump unit lowered up to a depth of about meters. The discharge pipe was projecting out, the pump remaining submerged.

The following are the salient features of the pump.

01. PUMP TYPE MSP 63506

0.2 NUMBER OF STACES 6

03. MAXIMUM OUTER DIAMETER 142.00mm

04. MINIMUM TUBE WELL DIAMETER 150.00mm ,

05. CAPACITY 250 LITRES PER MINUTE

06. TOTAL WORKING HEAD 66.0 METERS

07. CASING COMPONENT CLOSED CRAINED CAST IRON

08. IMPELLERS and WEARING RING GUN METAL

09. SHAFT STAINLESS STEEL

10. WATER LUBRICATED BEARING BRONZE

11. SHAFT SLEEVES: PUMP COUPLING I STAINLESS STEEL PIVOT STAINLESS STEEL

THE MOTOR

01. RATING 7.5 H.P.

02. SUPPLY VOLTAGE 3 PHASE 400/440 VOLT A.C.

03. SPEED 2900 R.P.M.

04. STARTING SYSTEM STAR/DELTA

05. ELECTIC CABLE SIZE 3 x 1.5 Sq.mm.

06. MOTOR CASING STAINLESS STEEL TUBES STARTER AND CASING ARE PROTECTED AGINST CURROSION BY FIRMLY EDHERENT COATING OF RUST PREVENTING PRINT STARTOR WINDING COPPER WINDING WITH WATER PROOF NON HYGROSCOPIC NON AGEING INSULATING MATERIALS

08 BRUSH BEARING BRONZE

09 THRUST BEARING CARBON

10 THE MOTOR IS PROTECTED AGAINST SAND AND SILT INFILLTRATION

Chapter 4

OBSERVETION WELLS

4. OBSERVATION WELLS

For measuring drop of piezometric surface or water table in response to pumping wells are installed for this purpose which are known as observation wells at different distance from the pumped well are required, 50 that results can be averaged and obviously erroneous data can be disregarded. Observation wells may be located 10 to 100 m from the pumping well. Lohman (1972) mentioned that a good arrangement consists of a pair of observation wells at a distance of one, two and four times the thickness of the aquifer from the pumped well. For case of unconfined aquifer, observation wells should be at a distance of at least 1.5 times the aquifer thickness from the pumped well.

If the water levels in the observation wells are affected by factors other than pumping the well, efforts should be made to correct the draw downs for these effects, especially if the drawdowns are relatively small. Some of the factors affecting water table are change in Barometric pressure, effects of tides, change in surface water levels, earth tides, pumping of other well in the aquifer and recharge of groundwater. If these factors are expected to affect water levels in the observation wells during pumping tests ground water level, should be observed for some time

Prior to pumping, so that tends can be extrapolated to the Pumping period (or correction of the observed draw downs.

To minimize the possibility that water levels in observation wells are affected by Compression of air the vadose zone, pumping test should be carried out when there is no heavy rainfall, flooding, or irrigation in the area. To avoid, reverse water level reactions, care must be taken that observation wells reach into true aquifer material.

Confined Aquifers

Confined aquifers are known as artesian or pressure aquifers. Occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata.

Now for evaluation T (Transmissivity) and S (Storage coefficient) of confined aquifer from pumping test data transient state method can be followed.

Transient State Method:

The calculation of T and S from the rate of drawdown of water levels in the observation wells due to pumping a test well of constant rate is based on the Theis equation.

$$s = Q/4\pi T \left[\int_u^{\infty} e^{-u}\, du/u\right]$$

Where ‘s’ is draw down and Q constant well discharge

$$u = r^2S/4Tt$$

On solving eq. (i) and (ii) we get.

$$s = Q/4\pi T\ [-0.577216 - \ln u + u - u^2/2x2! + u^3/3x3! \ldots\ldots]$$

The function in the bracket is Called the well function W(u).

Both U and W(U) are dimensionless

So equation (2) can be written as

$$s = Q\ W(U)/4\pi T \qquad \text{-----(4)}$$

on solving for T we get

$$T = Q/4\pi w(U) \qquad \text{-------(5)}$$

On solving equation (2) we get,

$$S = 4\ TU/r^2/t \qquad . ..\ (6)$$

Since u and W(u) are both function of ‘T’ and ‘S’ equation(5) and (6) cannot be solved directly, and it has to be solved by following methods.

4.1 SOLUTION

4.1.1 Theis solution

A graphical procedure for evaluating T and S was developed by Theis.

From equation (5), we get, Log S = Log O/47rT + log W (u).... (7) And from equation (6) we get, Log r2/t= log 4T/S + log(U).. . .(8)

So it can be seen that, since $Q/4\pi T$ and 4T/S are constants for a given test, the relation between log S and log r must be similar to the relation between log W(u) and log U. Thus, if S is plotted against r^2/t and W(u) against u on the same double-logarithmic graph paper, the resulting curve will be of the same shape but horizontally and vertical offsets by the constants Q/47cT and 4T/S. If each curve is plotted on a separate sheet, the curve can be made to match by superimposing the type curve, keeping the co-ordinate axis parallel. An arbitrary point on the matching curve is thin selected, and the coordinates of this matching point are read on both graphs. This yields related values of r^2/t, S, U and W (u). Which are used to calculate t and s.

4.1.2 Chows Solution

Chow developed a method of solution with the advantage avoiding curve fitting and being unrestricted in its application measurements of drawdown in an observation well near a pumped well are made. The observational data are plotted on a semi-logarithmic paper in the same way as for Cooper Jacob Method. On the plotted curve, choose an arbitrary point and note the coordinates, t and s. Next, draw a tangent to the curve at the chosen point and determine the drawdown difference S, per log cycle of time. Compute F(u) from

$$F(u) = S/\Delta S \qquad \text{----------------} \ (15)$$

and find the corresponding value of W(u) and U from the graph. Finally compute the formation constant T and S from equation (5) and (6).

4.1.3 Cooper-Jacob method of Solution

Cooper-Jacob noted that for small values of 'r' and large values of 't', U is small, so that the series terms in equation (3) becomes negligible after the first two terms. As a result, the drawdown can be expressed by the equation.

$$S = Q/4\pi T\ (-0.5771 - \ln r^2/s/4Tt)$$

Rewriting and changing to decimal logarithm this reduces to

$$S = 2.30\ Q/4\pi T\ \text{Log}\ 2.25\ Tt/r^2S$$

Therefore a p1ot of drawdown 'S' verses logarithm of t forms a straight line. Projecting this line to S = 0, where $t = t_0$

$$Q = 2.30\ Q/4\pi T\ \text{Log}\ 2.25\ T\,to/r^2S$$

and it follows that

$$2.25\ Tto/r^2S \qquad \text{--------------} \ (12)$$

Resulting in

$$S = 2.25\ Tto/r^2 \ \text{--------------} \ (13)$$

A value of r can be obtained by noting that if

$$t/t0 = 10 \text{ then } \log t/t0 = 1$$

Therefore replacing S by S', where S is the drawdown, difference per log cycle of 't'

Therefore, equation (10) becomes

$$T = 2.30\ Q/4\pi S \ldots \quad (14)$$

Thus first solve for T from equation (14) then solve for

S for equation (13) The straight line approximation for this method is restricted to small values of U(U 0.01) to avoid large errors

4.1.4 Recovery test

When a pumping test is conducted and the pump is stopped, the water level in the observation well will rise. Theis presented an equation for the residual drawdown ‘S’.

$$S = Q/4\pi T\ (W\ (U)\text{-}W\ (U')\ \text{----------}\ (1)$$

Where $U = r^2S/4\ Tt$ and $U' = r^2S/4Tt' \ldots (2)$

Which for small values of $r^2S/4Tt'$ reduces to?

$$S = 2.30/4\ \pi T \log t/t' \ldots .(3)$$

Where t is the time since pumping was started and t’ is time since pumping was stopped. (It is the total time of pumping + t’)

To solve this equation, S is plotted against t/t’ on a semi logarithmic graph paper. A straight line is fitted through the data points. The slope of this line is equal to $2.30/4\pi T$ and also to the change S and S per unit log cycle.

Thus T can be calculated as

$$T = 2.3\ Q/4\pi\Delta S \ldots (4)$$

The recovery test which is used as a check on T calculated from drawdown data during pumping, does not yield S

Chapter 5

ANALYSIS OF RESULTS

5 ANALYSES OF RESULTS

5.1 OBSERVATION AND COMPUTATION TABLE FOR THEIS METHOD

5.1.1Pumping out Test

Distance of observation well and pumping we1l=l0.5m

Constant discharge 1070 gallons/hr.

= 97.07 m^3/ day

Initial water level was at depth of 6.68 meters from ground surface.

The curve "r^2 /t" verses "s" was plotted and

Superimposed on this standard curve of W (u) verses u the corresponding readings on coincident zone and the calculation areas follow:

r^2/t = 6.7 m^2/minute

U = 0.l

S = 0.57 meters.

W(u) = 1.0

T = Q/4πS . W(u) = 97.07 x 1/4x3.14x0.57

= 13.55 m^2/day

S = $4TU/r^2/t$

= 4xl3.55x0.1/6.7x24x60

= $5.6x10^{-4}$

5.1.2 THEIS REVERSE TYPE CURVE METHOD

A curve between W (u) & 1/u i.e. type curve and between S and t/r^2 i.e. field curve can be plotted on the

Log-log graph. After matching these following values have been taken.

W (u) = 1.0 and 1/u = 10.0

t/r^2 = 0.16 min/met^2

S = 0.55

Q = 97.07 m^3/day

T = Q W(u)/4S = 13.79 m^2/clay

S = $4TU/r^2/t$ = $4.31x10^{-4}$

5.1.3 COPPER -JACOBI METHOD

The solution given by Jacobi for non-equi1ibri radical flaw is as:

$$S = 2.3\, Q/4T \log 2.25Tt/\, r^2\, s$$

Where S = draw down at a distance r = 10.5m away

Q = Constant discharge 97.07 cum/day

T = Transitivity coefficient of the confined Aquifer

t = Time in minutes since pumping started

S = Storage coefficient of confined aquifer

A graph is plotted between S and log t, it will give a straight line. Now, the various draw downs have been plotted on y axis of a semi log graph paper, plotting t on x-axis (.Log scale). The straight line that best fitted the points was then drawn through them. The line was intended to intersect the x-axis at a point say, to.

From the graph we have

t0 = 3.1 minute

s = 1.22 mtrs.

T = 13.51 m^2/day

S = 5.9×10^{-4}

5.1.4 CHOW'S METHOD

A curve of 'u' was plotted on a log log graph paper taking W (U) on the X axis and F(u) on the Y axis.

Now choosing an arbitrary part 'p' on the Jacobi's drawdown vs. log time curve (straight line), which refers to

S = 1.3 m

t = 3 min

F (u) = 0.392

For this value of F (u)

W (u) = 0.5 from Chow's curve

U = 0.55

T = 12.8 m^2/day

S = 5.32×10^{-4}

5.2 RECOVERY TEST DATA ANALYSIS

Pumping was stopped after 130 minutes.

$$S = 1.413 \text{ m}$$

$$T = 2.3Q/4S$$

$$= 12.6 \text{ m}^2/\text{day}$$

A graph has been drawn between Residual draw down versus log T/t' on a semi log graph paper taking the former on plane Scale and the later on the log scale. The graph comes to be straight line. Straight line per log cycle i.e. s comes to be 0.525 meters from the graph.

5.3 Table of results from different methods of analysis:

Method	***Transmissibility*** (T) In m^2 /day	***Storage coefficient*** (S)
1 Theis Method.1	13.55	5.6×10^{-4}
2. Theis Method.2	13.79	4.3×10^{-4}
3. Copper Jacob Method	13.10	5.9×10^{-4}
4. Chow's Method	12.8	5.32×10^{-4}
5. Recovery Test	12.6	----
Average value	13.168 m^2/day	5.28×10^{-4}

Chapter 6

QUALITY OF WATER

6. QUALITY OF WATER

The quality of water must be ensured before it is supplied for any purpose. Different organizations have recommended different standards for water to be used for different purposes. Appendix-2 Contains the different recommended concentrations of various impurities for drinking water as given by WORLD HEALTH ORGANISATION (WHO) and INDIAN SCIENTIFIC ORGANISATIONS. The water noticed during the pumping test was absolutely clear which may be safely used for landscaping purposes.

6.2 MANAGEMENT OF GROUND WATER

Maximum development of groundwater resources for beneficial use involves planning in terms of an entire groundwater basin. Recognizing that a basin is a large Natural underground reservoir, it follows that utilization of groundwater by one land owner affects the water supply of all other land owners. Management objectives must be Selected in order to develop and operate the basin. These involve not only geologic and hydrologic considerations but also economic, legal, political, and financial aspects. Typically, optimum economic development of water resources in an area requires an integrated approach that coordinates the use of both surface water and groundwater resources. After evaluation of total water resources and preparation of alternative management plans, action decisions can then be made by appropriate public bodies or agencies.

Four levels of study are generally recognized, although not all are required. In brief these include:

6.2.1.1 Preliminary Examination:- Based largely on judgment by experienced personnel, thus study identifies the management possibilities of meeting a defined need for a specified area.

6.2.1.2. Reconnaissance: — this study considers possible alternatives in the formulation of a water management plan to meet a defined need for an area, including estimates of benefits and costs. The investigation draws on available data and generally necessitates a minimum of new data collection.

6.2.1.3. Feasibility: — this study requires detailed engineering hydrogeology. and economic analyses together with cost and benefit estimates to ensure that the selected project is an Optimum development. The sequence of activities normally Involved in a feasibility investigation is outlined .Typically, the investigation concludes with report recommending approval and funding for the project.

6.2.1.4. Definite Project: **—** this investigation involves planning studies necessary for defining specific features of the selected project. The completed report forms the basis for starting final design and preparation of plans and Specifications

CONCLUSION

CONCLUSION

The Rourkela hilly terrain and its surroundings receive an average rainfall of more than 150 cms and hence command a high ground water potential in its confined aquifers. The hilly terrain has although a very high ground water potential by Virtue of its fissures faults openings etc. It has limitations with respects of quality contributed by type of deposits or formations and hence quality of water is not always satisfactory. Further due to rapid urbanization and growth of Industry, there is always a possibility of waste water or pollutants entering the ground water formations. Hence the quality of ground water has to be properly investigated before establishing the suitability of its use for various purposes.

The results obtained from pumping and recovery test for the well at the site near D-BLOCK N.I.T CAMPUS is more than satisfactory. A very high value of storage coefficient was obtained for other wells indicating that this point can meet the requirement of the water for the college and campus to a large extent. However, a proper Planning is to be evolved for use of this ground water on Consumptive use basis. The ground water scheme can be a supplementary one to the existing surface water system. As there is no near by ground water point tapping water from this aquifer, there is less scope in the interference for draft Over The pumping test in the well shows a satisfactory recovery after pumping is stopped. This indicates a high Storage coefficient and that the supply may be assured to meet the drinking water requirement even in dry season. Thus the cost of further treatment is saved. We may arrive at a conclusion that ground water from the well under study can meet the demand of potable water to a large extent for National Institute of Technology, Rourkela and its Campus. Thus the project is considered to be a success.

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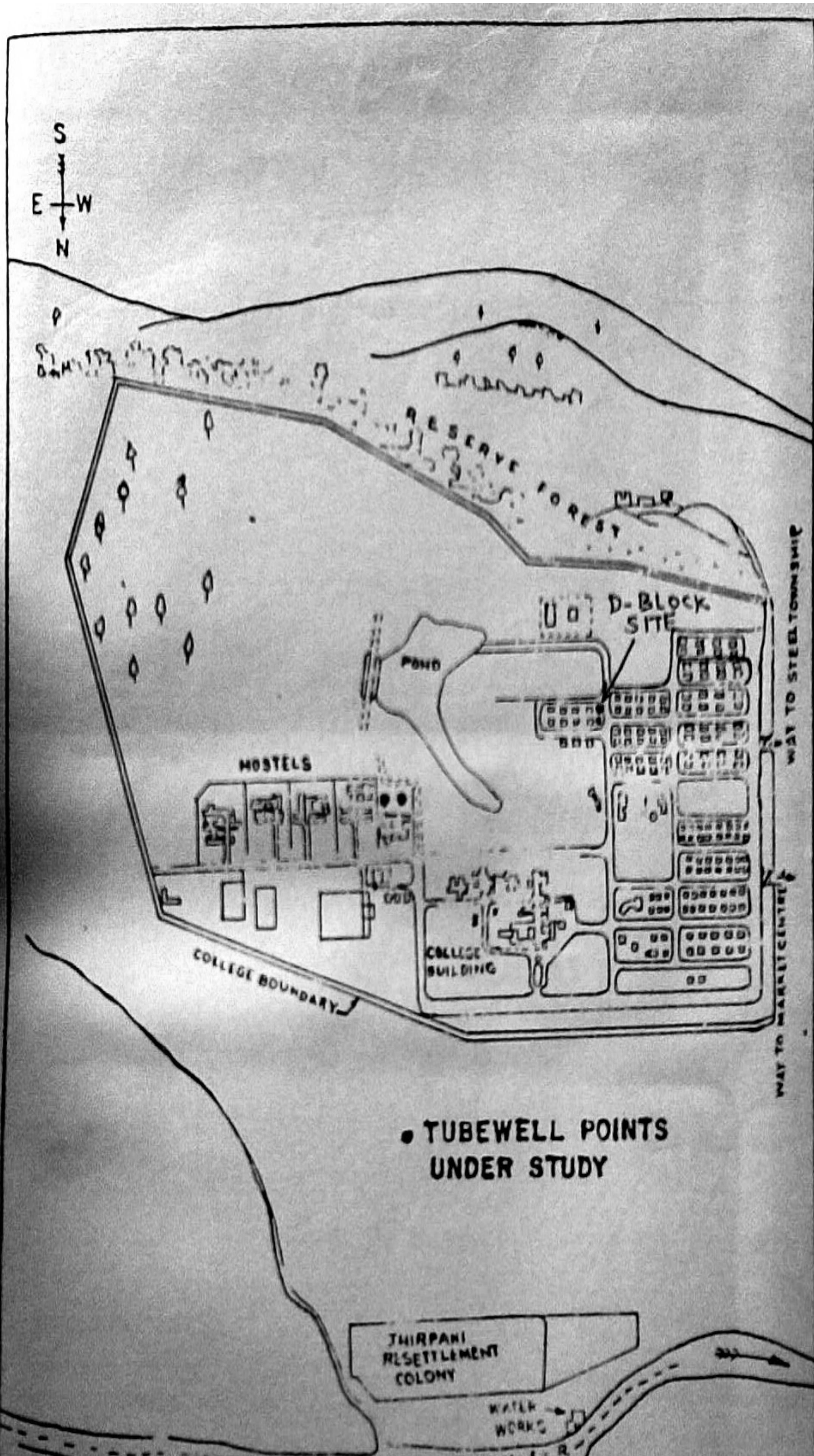
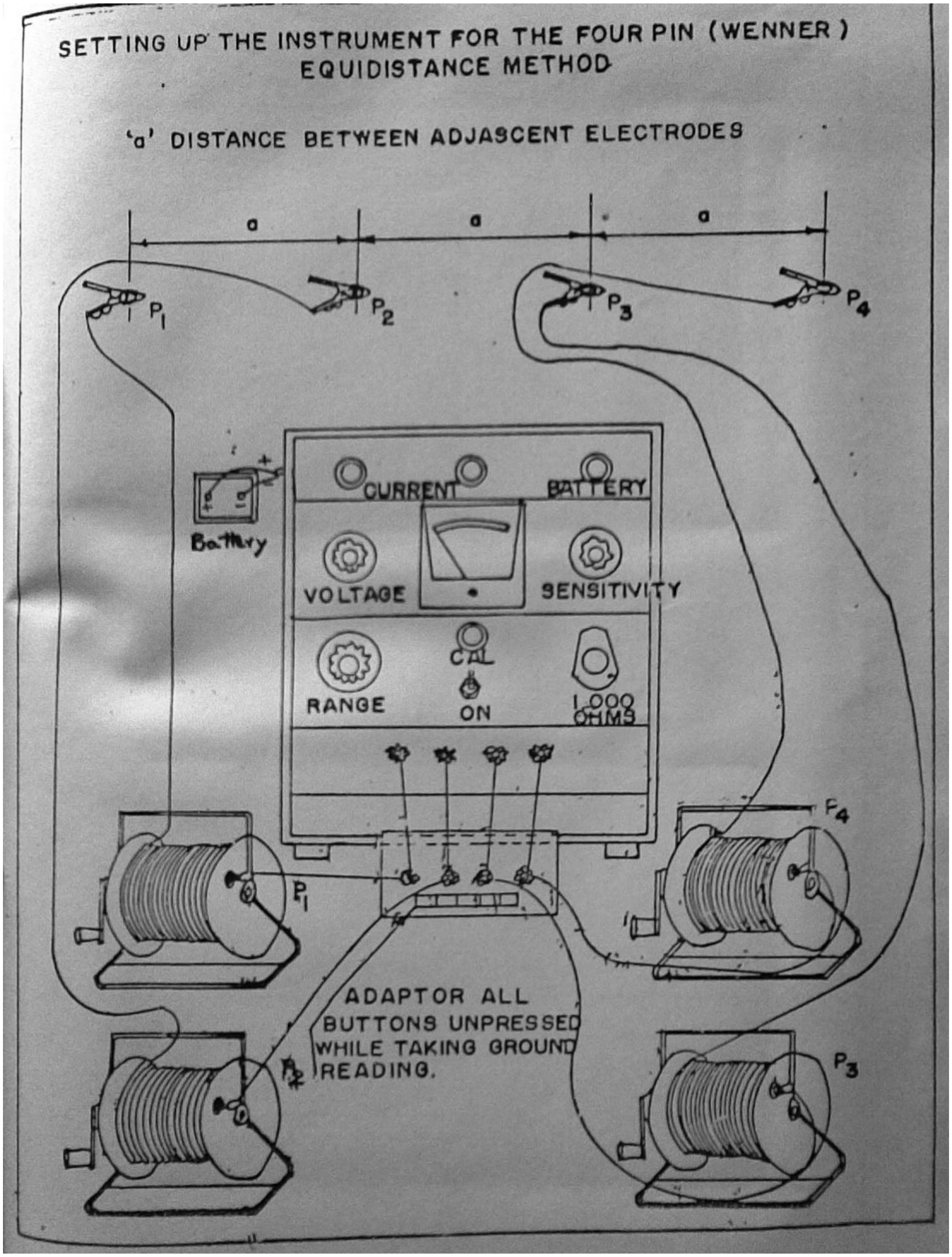
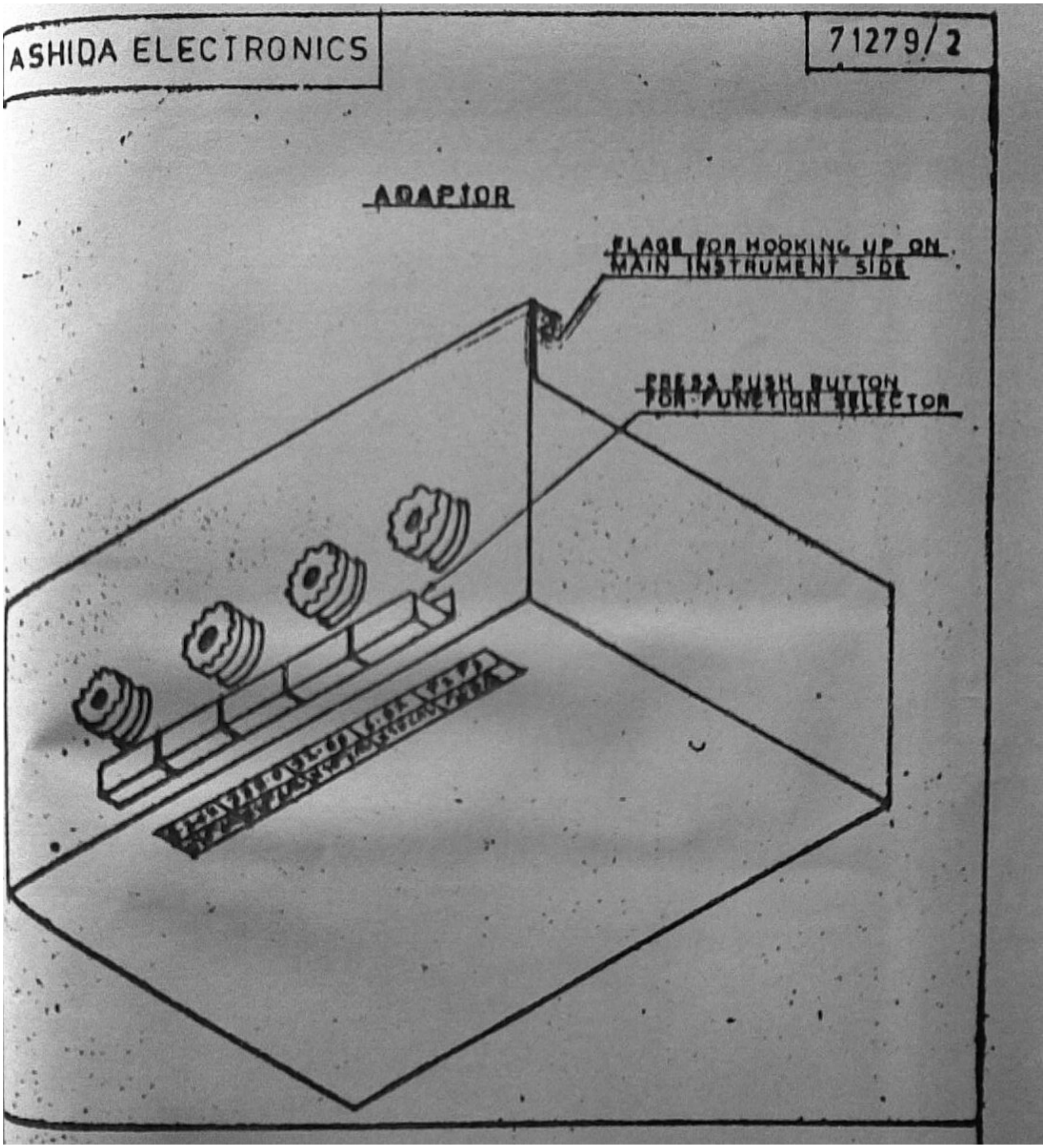

S
E
W
N
RESERVE FOREST
D-BLOCK SITE
POND
HOSTELS
COLLEGE BUILDING
COLLEGE BOUNDARY
WAY TO STEEL TOWNSHIP
WAY TO MARKET CENTRE
• TUBEWELL POINTS UNDER STUDY
JHIRPANI RESETTLEMENT COLONY
WATER WORKS


SETTING UP THE INSTRUMENT FOR THE FOUR PIN (WENNER)
EQUIDISTANCE METHOD
'a' DISTANCE BETWEEN ADJASCENT ELECTRODES
a
a
a
P1
P2
P3
P4
Battery
CURRENT
BATTERY
VOLTAGE
SENSITIVITY
RANGE
CAL
ON
1,000
OHMS
P1
P4
P2
P3
ADAPTOR ALL
BUTTONS UNPRESSED
WHILE TAKING GROUND
READING.


ASHIDA ELECTRONICS
71279/2
ADAPTOR
FLAGE FOR HOOKING UP ON MAIN INSTRUMENT SIDE
PRESS PUSH BUTTON FOR FUNCTION SELECTOR

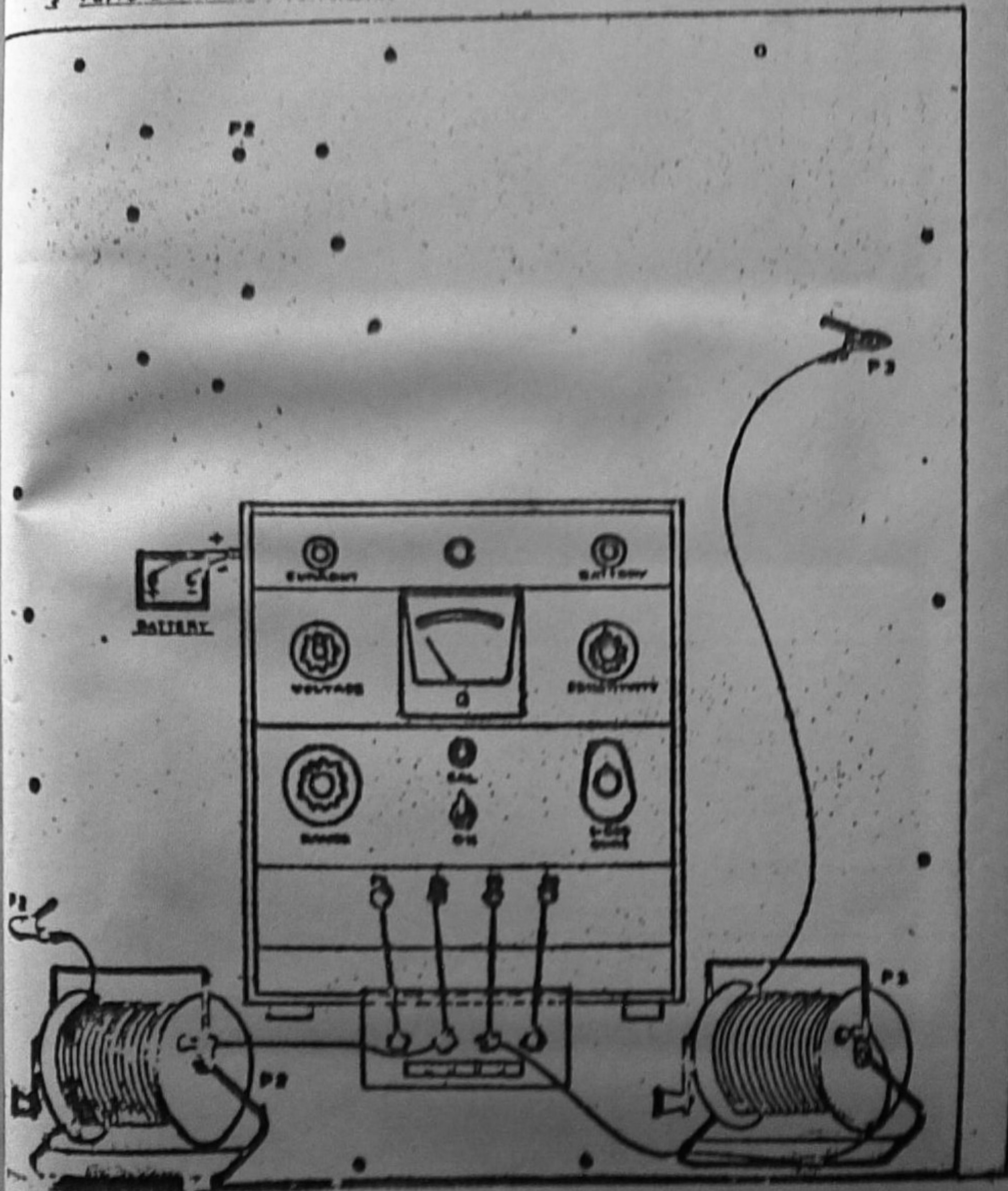
ASHIDA ELECTRONICS

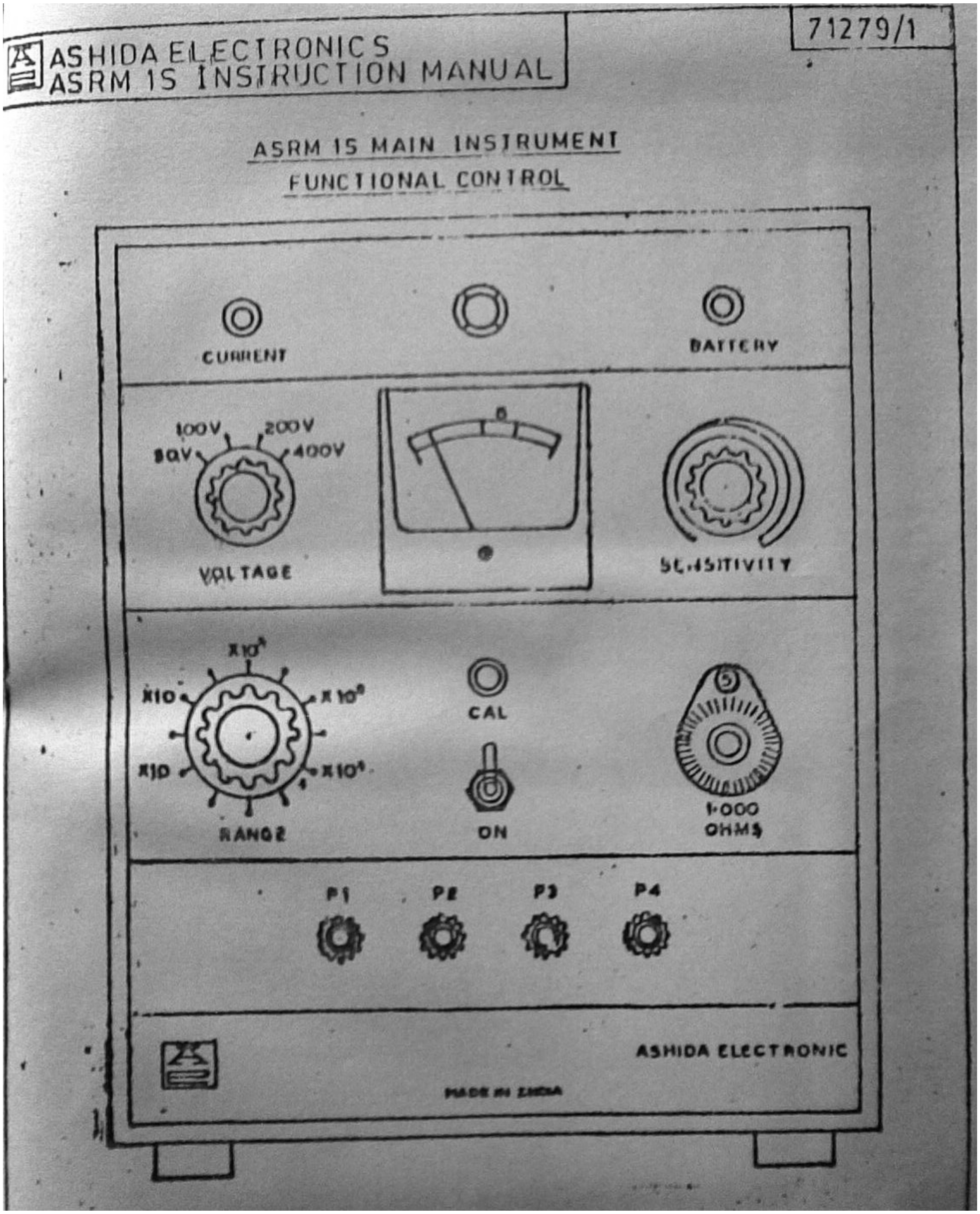
71279/6

ASRM 2PIN METHOD FOR SELECTION OF A BEST SPOT FOR GROUND WATER EXPLORATION IN A GIVEN AREA:

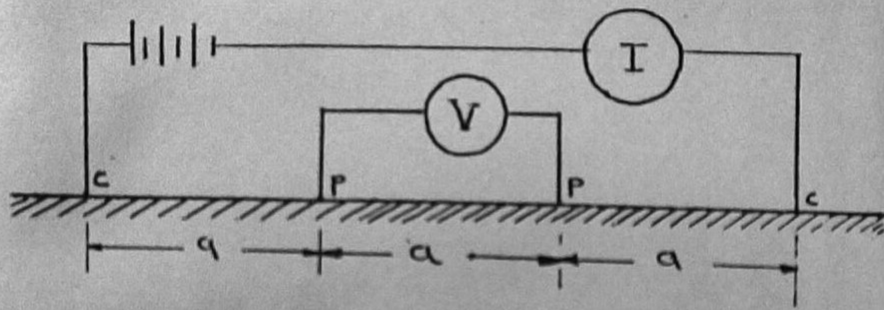
NOTES:—

1 ADAPTOR END BUTTON 'ASRM 2PIN' IN PRESSED CONDITION:
2 P3, IS REFERENCE ELECTRODE:
3 P2, IS SEARCH ELECTRODE·

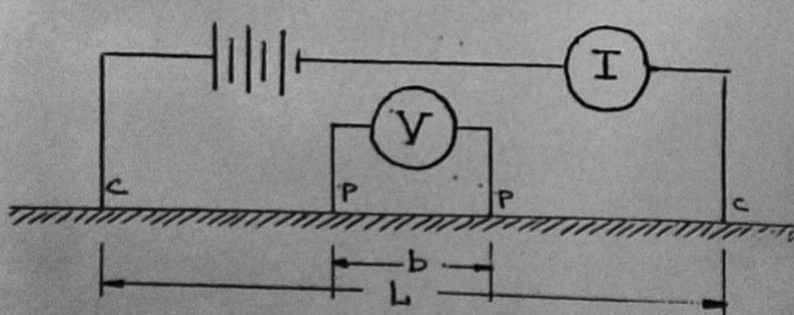



71279/1
ASHIDA ELECTRONICS
ASRM 1S INSTRUCTION MANUAL
ASRM 1S MAIN INSTRUMENT
FUNCTIONAL CONTROL
CURRENT
BATTERY
100V
200V
400V
VOLTAGE
SENSITIVITY
CAL
ON
RANGE
1·000
OHMS
P1
P2
P3
P4
ASHIDA ELECTRONIC

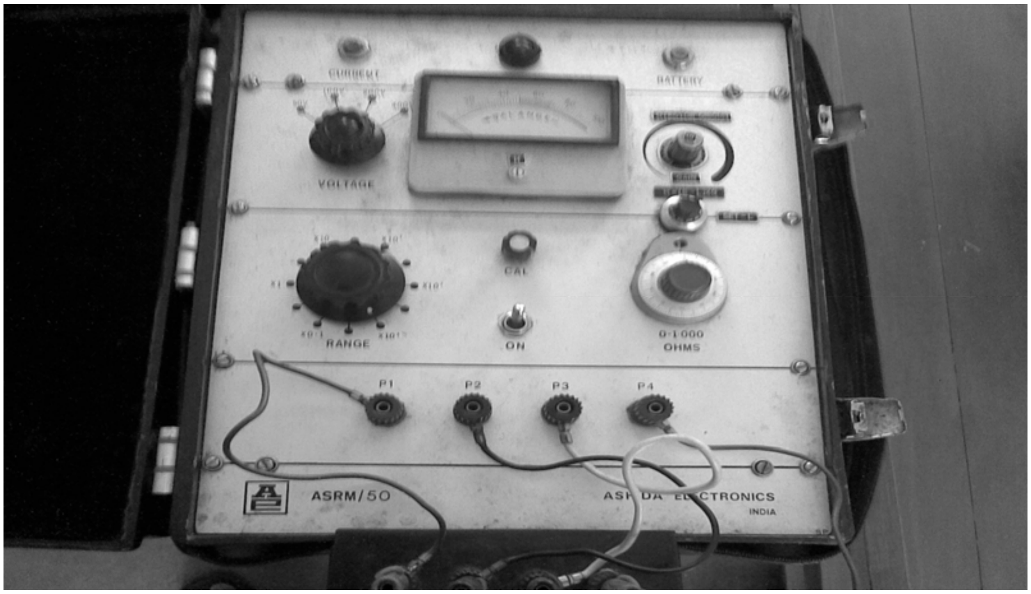
(a) WENNER ELECTRODE ARRANGEMENT



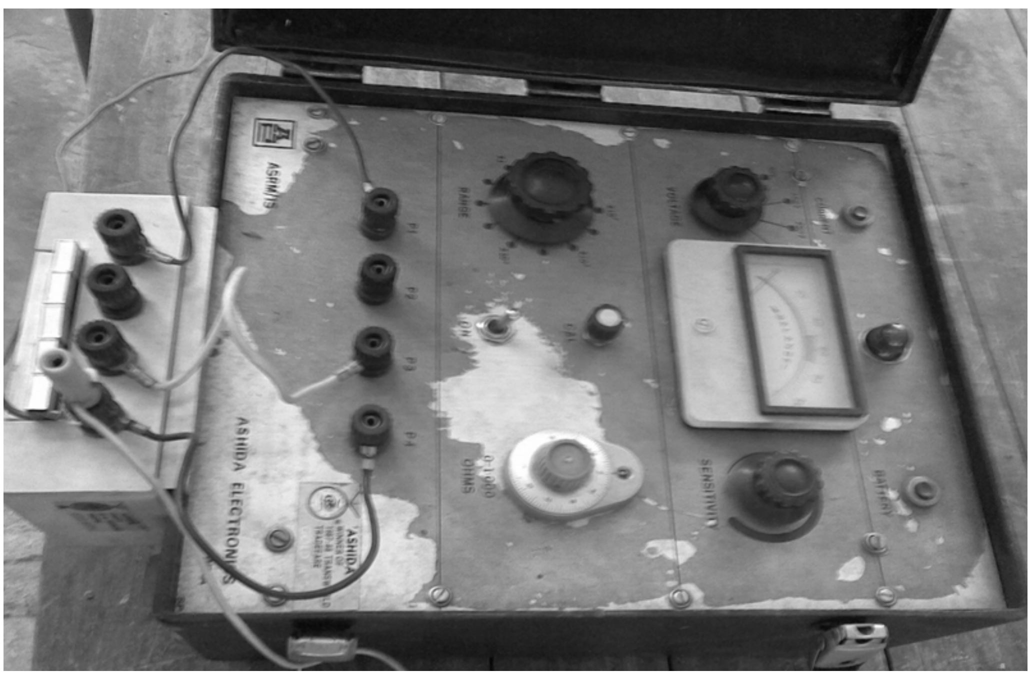
(b) SCHLUMBERGER ELECTRODE ARRANGEMENT



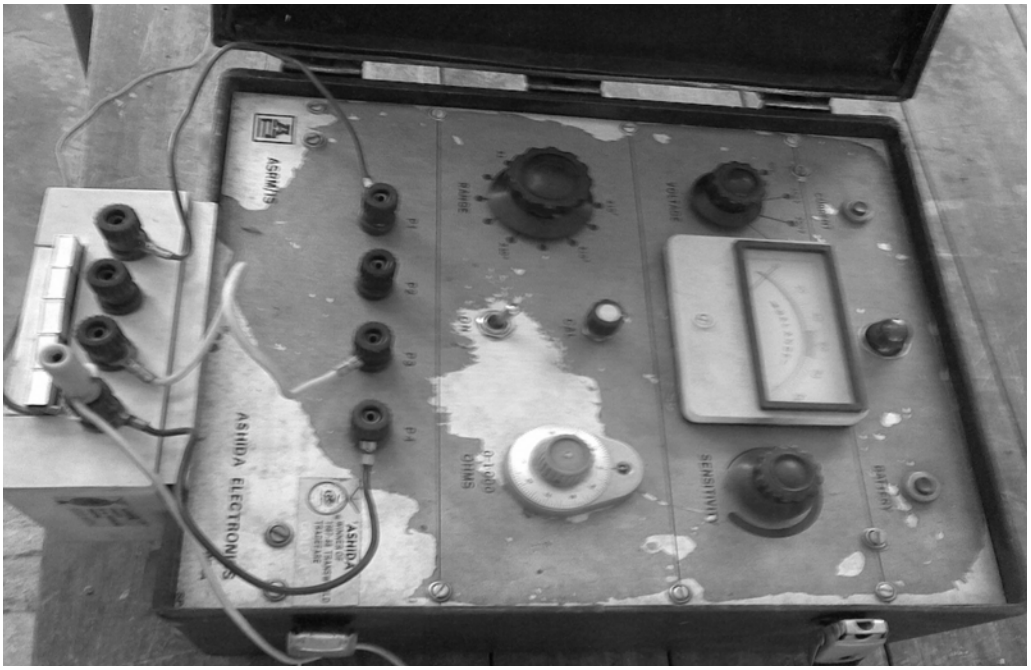
PROJECT PHOTOGRAPHS



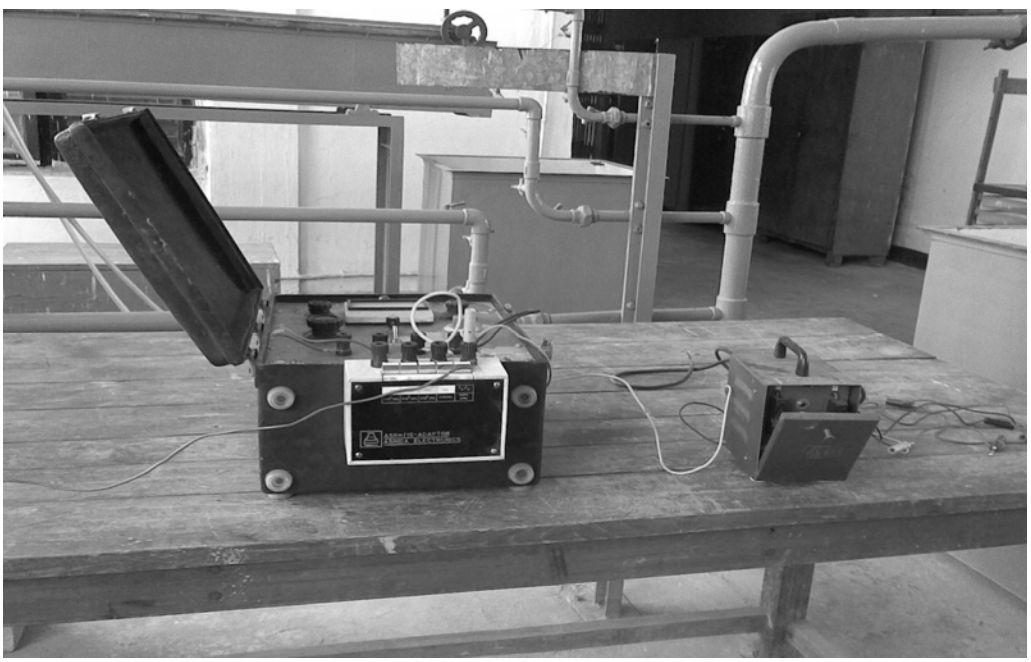
Resistivity Measuring Instrument (Up to 300m depth)



Resistivity Measuring Instrument (Up to 100m depth)



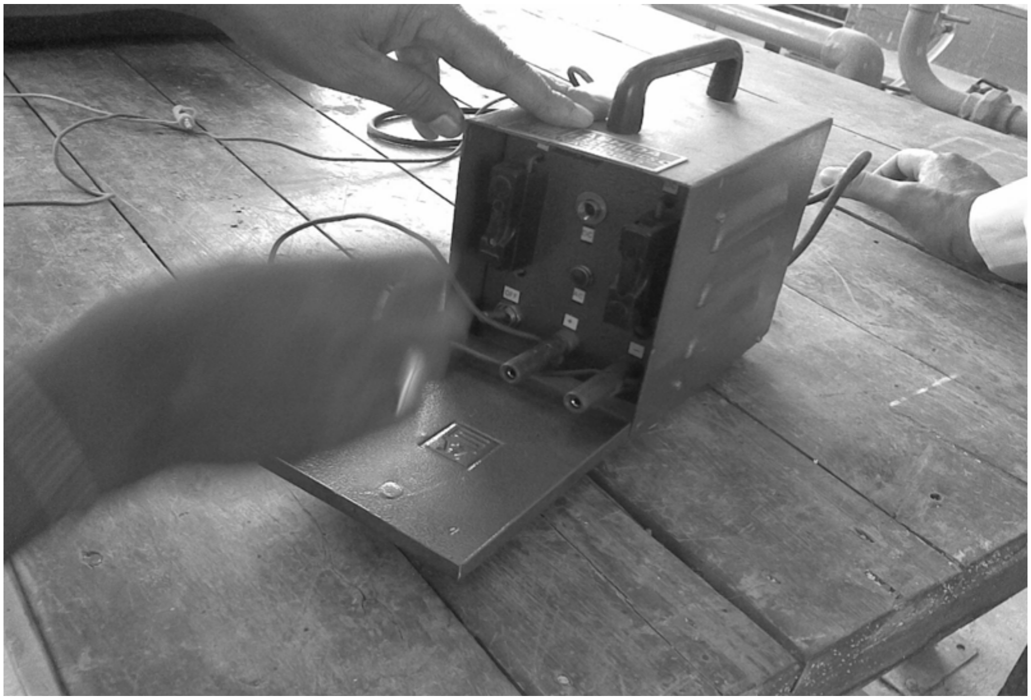
Panel of the Resistivity Measuring Instrument



Wenner’s Configuration

Carbon Steel Metallic Probes


Guide and the Student in the lab



Connecting the Adapter

Demonstration of the Instrument

Connection by the Lab Assistants

Demonstration of Insertion of the metallic probes